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(54) TREATMENT OF ANIMAL WASTE TO PRODUCE MATERIALS FOR USE IN ANIMAL FEEDSTUFF OR ON THE LAND

(71) We, WELWYN HALL RESEARCH ASSOCIATION, a British body corporate, of 11, White Lion House, Town Centre, Hatfield, Hertfordshire, AL10 0JL, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns the treatment of animal waste in the form of dung and urine from animal farms, to produce materials for use in animal feedstuff or on the land.

The invention has as an object the mitigation of the environmental nuisance and damage caused by the accumulation of animal farm wastes and in particular the control of odours resulting from intensive in-house husbandry. A further object is the reduction of the concentration of ammonia in pighouses, thus making conditions better for the animals and for farm workers and, by reducing the need for vantilation, saving costs of animal house heating. A further object is the preservation of the total fertiliser value of the slurry of mixed dung and urine for application to the land and the production of an odourless and stable soil conditioner with liming properties. A further object is the effective destruction of pathogens in the slurry before application to land, to prevent the infection of stock on treated grassland or of humans by windblown aerosols produced by rainguns used for land irrigation. A further object is a method of dealing with an infected herd which would otherwise be continually re-infected from its own excreta. A further object is the conversion of the nitrogen and other values of the waste slurry into a useful proteinaceous feedstuff supplement, free from pathogens, which can be fed back to the animals. The normal cycle whereby the slurry is used as fertiliser on the land and the feedstuff value is recovered in the form of a crop, probably with a rather low protein content, is thus shortened by the direct microbiological production of protein. A further object is the saving of water by partial recirculation and the production of a final effluent water of a good standard for discharge to a watercourse. A further object is to avoid the costs and unpleasantness involved in storage of, and in disposing of, noisome wastes from an intensive farm of small area by transport to and distribution on the land of the same or of neighbouring farms.

Where a number of animals is maintained in in-house conditions, large amounts of waste matter are produced. It is seldom possible to distribute this immediately on to farmland because of weather or the growing conditions of the crops. Storage with biological treatment is practiced. Storage can be in lagoons or in heaps. The former is appropriate if the animal waste is dealt with by a washing or slurry process and the latter if the waste is mixed with straw to make farmyard manure which can be stacked and matured. The slurry processes have the advantage of economy in labour. In both processes there is a loss of nitrogen fertiliser value as ammonia gas either from the lagoon or stack or after spreading on the land. Ammonia is an excellent fertiliser. In both the lagoon and dry stack processes there is a considerable risk of the development of objectionable smells. This is most acute with pig waste handled by the slurry process.

The odours arise largely as a result of the action of anaerobic bacteria. It would be expected that this problem could be overcome by treatment with chemicals which would inhibit microbiological activity. The use of disinfectants such as chlorine would not, however, be acceptable generally, or for the purposes of this invention, because of the risk of inhibition of microbiological activity required later or after incorporation in the soil. Other disinfectants would appear to be unacceptable because they would be cost ineffective, or because they have insufficiently long-lasting effects. It is known

and has been widely practiced in the past, to treat decomposing animal matter with quicklime or hydrated lime or other strongly alkaline material in order to sterilise it and to reduce the odour. In the case of manures or slurries normally available on the farm, however, such use would lead to intense ammoniacal smells and to loss of nitrogen values from the material to the atmosphere.

The ammonia present in animal house slurry as at present known results from the action of urease enzyme upon the urea present in the urine. Further but less ammonia may result from the decomposition of nitrogenous compounds in the dung. This ammonia is largely present as ammonium compounds; these are decomposed on addition of alkaline material such as lime with liberation of ammonia with resulting choking smells.

Urine as excreted is effectively sterile and without urease enzyme. Dung, on the other hand, is highly biologically active and, if urease enzyme is not present on excretion, it is rapidly produced by the proliferating microorganisms from the dung on admixture with the urine.

Under farming conditions it is not possible to keep the urine and dung from the stock separate, so that the urea rapidly changes to ammonia and ammoniacal compounds with consequent environmental damage and value loss.

It is reported from chemical laboratory work that the action of the urease enzyme in converting urea to ammonia is inhibited by the addition of lime to give a pH value of greater than 11. It is not shown in the prior art whether this operates under farming conditions in the presenec of a wide variety of microorganisms, bacterial nutrient compounsd and suspended solids of various types.

To the Applicant's knowledge no process has been disclosed in the literature or proposed for farm use where lime is mixed with animal dung to sterilise it. The reason for this would appear to be that it is expected that the result would, in all cases, be an intolerable liberation of ammonia. It is universally understood and is widely published, in particular in works on gardening, that soil must not be manured and limed at the same time, because of this effect.

According to this invention there is provided a method of treating animal waste arising in animal husbandry in an animal house to obtain products useful on the land or in animal feedstuff, which comprises contacting fresh animal dung and urine from mammals in an animal house before more than 25 percent by weight of the urea initially present on excretion has been converted to ammonia or ammonium compounds, with a sufficient proportion of lime or a mixture containing lime, to form an alkaline slurry of the dung and urine having a pH value of from 9.0 to 12.0.

The lime may be mixed with an alkali metal hydroxide, an alkali metal carbonate or another alkaline earth metal hydroxide. The lime is preferably provided in the form of quicklime in lump form or as powder, or hydrated lime as powder, lime putty or aqueous suspension (milk of lime) with or without addition of salts of multivalent metals, with or without a weighting agent which may be a fines-free calcium carbonate powder.

The pH value of the formed alkaline slurry is preferably at least 11.

The invention is especially applicable where the animals husbanded are pigs, but is useful with other animals and most particularly in intensive animal rearing houses.

Preferably the alkaline slurry is retained at said pH for a period of time sufficiently long to inactivate at the temperature of retention effectively all pathogens present, to yield at least one sterile product applicable to land as fertiliser or soil conditioner. At least part of said resulting sterile product is preferably treated by an aerobic microbiological process in such a way as to establish and maintain an effectively stable population of microorganisms, optionally with nutrient additions influencing the balance therein of carbon, hydrogen, nitrogen, phosphorus and potassium to yield and effectively pathogen-free biomass applicable as an animal feedstuff supplement. Preferably the microbiological process is performed at an elevated temperature not exceeding 50°C sustained at least in part by animal body heat retained in the dung and urine and heat of hydration of lime when used.

The invention also extends to the sterile alkaline material for use on the land and biomass applicable as an animal feed supplement produced by the method of the invention.

According to the invention there is also provided apparatus for carrying out the method on dung and urine freshly deposited in an animal house with collection means therefor, which apparatus comprises supply means in the animal house, controlled in response to pH value in the collection means and effective to feed the lime to said collection means containing freshly deposited dung and urine, in amounts of lime to form the alkaline slurry therein and maintain said alkaline slurry at the required pH. The apparatus preferably includes a quicklime store protected against carbonation and premature hydration of the lime, metering means responsive to slurry pH for feeding the lime, and a hvdrator for producing said lime as milk of lime from the quicklime.

In an embodiment the apparatus further comprises means for storing the alkaline slurry for the residence time required to inactivate the pathogens, and an aerator suitable for an aerobic microbiological process of the activated sludge type, with means for continuous supply of said sterile product thereto. Preferably a bed of calcareous material is removably located in the aerator, for deposition thereon of calcium carbonate produced by reaction of lime and carbon dioxide from the aerobic microbiological process.

Quicklime is a preferred material because the heat of hydration helps the sterilisation process and helps to maintain the temperature of the medium for the production of biomass from the microbiological digestion process at the optimum of between 40°C and 45°C.

In the above the term "fresh" is used. In large-scale animal husbandry it is important that minimum labour should be employed for the clearing of excrement from animal houses. Accordingly it is customary for the floor of these houses in the dunging area near the water supply to be formed of slats or be sloped and slotted. This enables the urine to flow directly and immediately through to a tank or, possibly directed by V-shaped collecting panels, to a horizontal drainpipe or to a channel. If the tank or channel is filled with or periodically flushed by alkaline liquor based on lime, with adequate mixing, the urea of the urine is made alkaline before it makes contact with the microorganisms or urease enzyme from the dung. The dung normally rests for a period on top of the slats until it is trodden through by the animals. The limited contact of this dung with urine in the absence of lime before the whole passes through the slats, is not completely avoidable. This does not however, impair the achievement of the main object of this invention. It is proposed as part of the operation of this invention that the dunging area of the animal house is regularly washed down with the alkaline liquor as a sanitary precaution. This avoids any accumulation of old dung wetted with urine and untreated with lime.

Thus, the large bulk of the urine produced may be treated with lime within a period of seconds of its excretion. This effectively stops any significant conversion of the urea to ammonia. The flushing with alkaline liquor of the channels beneath the animal house can be carried out by continuous flow or by means of a self-emptying tipple tank which operates by a constant stream of liqffuor fed to it. A tipple tank tips when it becomes full so that a flush of liquor passes down the channels beneath the animal house and clears them completely. When empty the tipple tank reverts to its former position and re-filling commences.

It would be possible, though not convenient, to operate the process of the invention in an animal house with a solid floor. In this case the dung and urine would be mixed together and the floor would have to be scraped regularly into a tank containing the lime. It is not possible to give a definite time of treatment of such a mixed slurry with the lime effectively to remove pathogens. It will depend upon the degree of mixing of dung and urine, the temperature, and the amount of ammonia production which can be accepted. It is important that the pH is raised to at least 9.0 and preferably to at least 11.0 before too much conversion of the urea to ammonia has taken place.

Under the most satisfactory conditions the pH is raised before there is any appreciable odour of ammonia. The present invention extends to, and the term "fresh" embraces, the treatment of dung and urine wherein not more than 25 per cent of the urea initially present on excretion has been converted to ammonia or ammonium compounds. Once the pH has been raised, little further urea decomposition takes place. Before mixing with the lime, the rate of decomposition of the urea is governed largely by the temperature. In hot weather it can be very rapid. It is only by experiment that it could be determined how frequently it would be necessary to scrape the floor of a solid floor animal house. It is believed, however, that even in hot weather, provided that the mixing of the dung/urine slurry with the lime takes place within thirty minutes, there will not be appreciable production of ammonia.

In any particular case it becomes clear when the mixing of excreta and lime has not taken place soon enough, because of the smell of the ammonia that is produced.

In the case of a herd of pigs or other animals infected by Salmonella or other pathogens it may be necessary to employ special devices for keeping the dunging area clean and preventing reinfection of the herd from its own excrement. The individual smaller unit, for example a pighouse, would be cleared of animals temporarily and the area treated with a suspension of hydrated lime in water, or by alkaline liquor provided by a later stage in the operation of the process of this invention. The floor can be cleared by means of a scraper or brush and the walls sprayed. The alkaline slurry washings would be swilled from the animal house through floor slots down into a tank or horizontal drainpipe or channel as part of the treatment with a base according to the invention. After leaving for a time for the lime to act, the area may then be washed

down by fresh water or by water recirculated from a later stage in the full method of this invention.

The use of lime rather than soda or soda ash is advantageous for several reasons. It costs less for a given alkali value. It is less dangerous than caustic alkalis, and the metal calcium is preferred to sodium in fertiliser or in animal diets. On exposure to the atmosphere, unlike caustic alkalis, milk of lime rapidly becomes innocuous by absorption of carbon dioxide to form calcium carbonate, which is not only non-toxic but indeed beneficial in reasonable proportions in animal or human diets. It has been traditional to limewash farm buildings, this having a sterilising effect.

The soluble calcium which is introduced into the system is precipitated as calcium carbonate which, when the process is appropriate, can be removed by precipitation onto the calcareous substrate. If caustic alkalis or alkali metal carbonates are used there is no real possibility of removing the dissolved metal ions from these materials. Build-up in the recirculating water is unavoidable. Other difficulties such as the high proportion of carbon dioxide required to neutralise alkali metal hydroxides can be envisaged.

The use of quicklime rather than hydrated lime as the initial supply of lime is advantageous from the standpoint of economy and because the heat produced by the hydration process aids the sterilisation. Lump quicklime of graded size and of chosen quality is not dangerous to handle, is not subject to problems of unpleasant blown dust and can be safely and conveniently supplied to small silos. There is little deterioration on storage in a covered silo. There are no problems of blocking or bridging in the silo and the quicklime may easily be metered by known equipment, together with water, into a continuously operating device where hydration may be carried out to give milk of lime. Fresh water should be used for this but recirculated water may be considered.

The proportion of lime required to give the appropriate alkaline pH value depends on the hardness of the water on the farm.

The alkaline slurry, which may be diluted with water recirculated from a later stage in the operation of the process, is then allowed time for the sterilisation by the lime to occur. This may be done by leaving it in a tank gently stirred for a period and then allowed to settle or by a continously operating upward-flow separator using a sludge blanket. In both cases lime operates as an excellent sludge conditioner, enabling separation into a clear supernatant liquid and a semi-solid settlement to take place. This process can be aided if necessary by the addition of salts of non-toxic multivalent metals. The presence of a particulate weighting agent aids the separation.

It is noteworthy that the process of sterilisation by lime and the consequent odour reduction enables the clear alkaline supernatant liquid from the separation process to be recirculated through the animal house after topping up with lime. This causes a build-up of nutrients so that the final product can be a concentrated liquid fertiliser, the application of which to land requires a decreased volume for a given fertiliser value so that transport and application costs are reduced.

The sterile material produced as above can be utilised without further treatment. It may be stored, whereupon it will maintain its fertiliser value, having suffered little loss of ammonia, until conditions are favourable for application to land. It may well be found convenient to apply the clear liquid through a spray bar or a raingun. With the former, danger of blockage of the distributing holes is minimised and with the latter there is no danger of infection being carried in the wind by aerosols containing pathogens. Due to its sterility, if this liquid is distributed on grassland, stock may be turned on to the land area as soon as the animals will accept the grazing. Calcium is valuable in the diet of milk-producing animals. Urea is acceptable as a component of the diet of ruminants. It is a great advantage that the nitrogen content of this liquid fertiliser remains as urea and is not present as ammonia or ammonium compounds. Before the carbon dioxide from the atmosphere has neutralised the alkalinity, the liquid penetrates into the ground, particularly if washed in by rain. In the ground there is adequate bacterial generation of carbon dioxide to neutralise the alkalinity when, as a result of biological action, the urea is converted to ammonia. In suitable clay soils this is at once fixed by the clay component of the soil and remains there to act as a plant nutrient until converted to nitrate, loss of which by leaching cannot be avoided.

The settled semi-liquid material from the sterilisation or the sterilisation/sludge blanket can be stored as such. It is suitable for a drying bed. Alternatively it can be further passed through a press band strainer, vibrating sieve or similar equipment. The liquid component which passes through the strainer, when conditions for land application are right can be diluted, preferably with recirculated water, so as to be suitable for distribution on agricultural land using, for example, a spray bar. Since there is little solid material present, most of the dissolved salts will soak into the soil, with a low tendency to form a surface

layer of decomposable organic matter. If such a layer is formed from lime-treated whole slurry, odours may be produced as atmospheric carbon dioxide neutralises the alkalinity and decomposition by micro-organisms starts in the surface solids layer. Such biodecomposition will, however, be aerobic in character and thus much less unpleasant than liquid from an anaerobic farm lagoon to which whole slurry has been fed; this can produce foetid smells.

The fibrous residue from the press band strainer which appears and feels "dry" can be spread on the land by a rotary distributor. It will not give rise to offence, because of the low content of rapidly decomposable material.

The storage on the farm of even low odour and sterile solids and liquids is, however, an awkward and expensive matter. Such storage is at present necessary to avoid the pollution of watercourses. The distribution of solid or liquid wastes on land is also expensive and difficult. It is becoming known to farmers neighbouring on intensive animal husbandry units that it is highly uneconomic for them to spread on their land stored slurry from the intensive unit, even if this is supplied to them at no cost. This procedure can also be dangerous, because of the spread of pathogens, possibly to stock on other farms. The fertiliser value of this slurry can at present prices be applied more cheaply and conveniently as artificial fertiliser and more easily at the optimum season, that of maximum plant growth and fertiliser utilisation.

It is therefore proposed that a further process is established on the intensive animal husbandry unit by which distribution of waste to land is reduced to the minimum, the fertiliser values being made available as a feedstuff supplement for consumption by the animals on the same or, where permitted by the regulations in force, on neighbouring farms.

One of the recommended methods for dealing with the problem of waste excremental matter on animal farms is the use of aerobic biological processes to stabilise the sludge, reduce its volume by oxidative decomposition and reduce the offensive and damaging character of effluent water. An example of this is the Pasveer Ditch. The treatment of the fresh animal waste with lime, with the retention of nitrogen values as urea, provides a sterile nutrient for the production by microorganisms of pathogen-free biomass for animal feed. Use of a small-scale activated sludge process is preferred, or a rotating type aerator such as the disc or Euro-Matic Bio-Drum.

The activated sludge process normally operates continuously, the slurry feed and air or oxygen being continuously supplied to one or more of a series of baffled tanks. In a later tank or tanks the biomass produced, known as 'activated sludge' is separated and part recirculated. The supernatant liquid can be water suitable for recirculation or other use, or for disposal to a watercourse. Excess activated sludge is continuously removed and may then be dewatered. In such a continuous process it is quite satisfactory to add a highly alkaline material, such as the clear supernatant liquor from settled lime-treated animal slurry, continuously to the aeration tanks. There is sufficient generation of acidic material, particularly carbon dioxide, by the process to accept the alkalinity without upsetting the operation of the process. Indeed the addition of alkali is recommended to accelerate microbiological action. It is also possible to pretreat the limed slurry with carbon dioxide to reduce this alkalinity. This carbon dioxide may be provided from the aeration tanks as it is a considerable product of the microbiological process. The product of reaction of carbon dioxide and lime, either carried out separately or in situ, is calcium carbonate, which may, if desired, be removed before the clear nutrient liquor is fed to the activated sludge process. Calcium carbonate is, however, a normal component of animal feed. On some farms it may be advantageous to feed continuously the whole of the lime-sterilised slurry, including fibres, to the activated sludge process. This provides a stabilised, calcareous, high value fertiliser and conditioner for agricultural land application.

It is advantageous to add biodegradable organic matter such as molasses or other nutrients to balance the carbonaceous nutrient for the biomass with the nitrogen, phosphorus and potassium (N, P, K) available from the slurry. Waste material such as straw is specially valuable for this. If straw is deposited in pits containing concentrated alkaline liquor and manure already sterilised by the present process, for a residence time sufficient for the straw to swell under the influence of base and urea, it will be more digestible by micro-organisms. By this means optimum production of biomass for the nutrients available is obtained. N, P, K held as biomass is less liable to be leached from soil by rain than when present as inorganic salts.

The feeding of the whole lime-treated slurry to the aeration tanks has an advantage over the feeding of the clear supernatant liquid from the settlement process. The soluble phosphate present is precipitated as calcium phosphate so that the clear supernatant liquid is denuded of phosphorus compounds. Phosphates are required as nutrient for the biomass in the aeration tanks, so that in this case a regular addition of phosphate will be required. This may

not be necessary if whole limed slurry passes to the aeration process.

During the time of standing at an alkaline pH for the sterilisation process two factors are in operation to increase the biodegradability of waste matter such as straw or the husks or fibres present in the slurry. The first of these is the alkalinity which causes the cellulosic structure to swell and liberate hemi-celluloses. The second is the presence of urea, which, because of its strong hydrogen bonding capacity, tends to open up and soften organic structures.

In the embodiment of the proposed operation where the whole slurry is sterilised and biologically treated, the final biomass produced may contain fibrous matter as well as calcium carbonate from the neutralisation of lime by carbon dioxide generated by the activated sludge process. The proportion of this latter may be undesirably high, even for a feedstuff supplement. It is here that the presence of a weighting agent in the form of fines-free calcium carbonate shows a secondary function. Instead of the calcium carbonate being formed as fine particles which cannot easily be separated from the biomass, deposition occurs upon the calcium carbonate particles, as in the use of a sea shell to stop the furring-up of a kettle, or as in the pellet process of water softening by lime. On standing, these settle rapidly and can be separated and re-used. Fibrous matter can if necessary be separated by a simple press band strainer. If left in the feedstuff supplement, however, it provides required fibre and roughage.

Calcium carbonate is formed in the process, from three sources:

(1) from reaction of the added calcium hydroxide with the temporary hardness (calcium bicarbonate) of the water used on the farm;

(2) from reaction of the added calcium hydroxide with calcium bicarbonate present in the urine and faeces of the animals;

(3) from reaction of the lime used in the process with carbon dioxide produced by the aerobic digestion of the sterilised slurry.

If the water on the farm is very hard, the source (1) can be important but may be effectively eliminated by use of a water-softening process on the raw and possibly also on the recirculated water. The deposition of calcium carbonate particles from process (2) in intimate mixture with the slurry solids can only be reduced by use of a granular calcium carbonate weighting agent. In the case of the major source (3) however, deposition may occur on granular calcium carbonate suspended in the liquid during the aerobic microbiological process. Alternatively the carbon dioxide gas from this process can be passed through a column packed with limestone down which the alkaline sterilised slurry passes, so that neutralisation takes place in this column and the bulk of the deposition of calcium carbonate occurs on the limestone substrate. Alternatively the aeration tank may be so arranged that the liquor is circulated through a bed of limestone by air bubbles passing upwards through it, the limed liquor being added at a suitable place for deposition of calcium carbonate to take place on the limestone. The limestone bed may be held in a container separate from the aeration tank so that it may be removed by a sheer-legs hoist for cleaning or limestone renewal.

The final supernatant liquid from the activated sludge process, after separation of the biomass, can provide water of a sufficiently high standard for discharge to a watercourse. This water is particularly valuable for recirculation to earlier stages in the process. It may be utilised for washing down the base-sterilised animal house. It is also required for dilution of the nutrient liquor in or before feeding into the activated sludge process tank. This is necessary because the nutrient level in even the clear separated supernatant liquid from animal slurry is too concentrated for the operation of the microorganisms in the biological process.

For the activated sludge process it is necessary to provide dissolved oxygen. This is done by known means which may be the bubbling of air, the forcing of air below the surface by liquid jets, (the "plunging jet" method) or by surface aerators. Partly immersed rotating elements as in the Bio-Disc process or its modifications may be specially suitable in some cases. Aeration under pressure is a further possibility. If oxygen rather than air is used, the tank may be enclosed and the general efficiency and rate of the micro-biological treatment increased.

In carrying out the present process to optimum effect and especially for the production of biomass it is advantageous to conserve not only the heat developed biologically but also as much as possible the original body heat of the dung and urine, and where applicable also the heat of reaction of quicklime hydration, by covering and lagging the tanks which are used as steriliser, aerator, and so forth, as well as the associated conduits. Completely submerged aerator pumps and pump motors are useful in this context. Exhaust warm air from the pighouse or other animal house can also be utilised, in order to attain maximum heat retention and recirculation.

The invention is further illustrated and its operation made more clear, by reference to the accompanying drawings, in which:

Figure 1 is a flow diagram of a presently used piggery waste-disposal system; and

Figure 2 is a flow diagram of one of several embodiments of the invention, which utilises whole slurry.

In the piggery waste-disposal system shown in Figure 1, a pighouse 1 is equipped with a dunging area and suitably slotted floor 2 and a waste sump 3 below the floor. Liquor from a flush tank 4 is recurrently supplied through a conduit 5 to wash through the sump 3 to carry away as slurry, dung and urine which has passed through the floor. The slurry passes via drain 6 to be stored in an anaerobic lagoon 7, from which the top liquor overflows through conduit 8 and flowmeter 9 to an aerator tank 10 provided with agitation means and into which air is blown as symbolised at 11, for aerobic digestion of the waste.

The aerated liquor passes through conduit 12 to a separator 13 from which a final liquor 16 is taken as an upper fraction. The solids settle in the lagoon 7 and are joined by further solids from separator 13 through conduit 14. Liquor from lagoon 7 is also recycled to the flush tank 4 via pipe 15.

In this system every attempt is made to destroy the biological oxygen demand values in the liquid part of the slurry by biological action in the aerator. The solids from this and from the original slurry are settled out in the large anaerobic lagoon and are cleared to land every six months. The fertilising and soil-conditioning effects of this solid material are the only values retained from the piggery waste. The solids from the aeration stage cannot be fed back to the pigs because the aeration process is not sufficiently effective in destruction of pathogens.

Figure 2 illustrates the operation of the process and means employed for treating the waste from one or more pighouses using granular or lump quicklime. A pebble chalk quicklime (wet process chalk lime) is a preferred material because of its low dustiness and its good rate of hydration. This enables a simple continuous hydration operation, based on a water spray which actuates a rotating sieve, to be effective. Limestone lump lime can also be used to advantage.

In the system shown in Figure 2, a pighouse 1 is equipped with a dunging area and suitably slotted floor 2 and a waste sump 3 below the floor, which can be continuously or regularly flushed with alkaline liquor. A store of quicklime 17 and a source of fresh water 18 are provided, and means 19 responsive to required pH are used to control the supply of hydrated lime, formed by suitable combination of lime and water from these sources, through conduit 20 such that the pH value in sump 3 is maintained above 11. The lime may be sprayed with water in a continuous hydrator with fresh or purified water to give a continuous milk of lime feed to the pighouse.

The freshly produced slurry of the dung and urine which has passed through the floor is thus treated with lime in the sump 3, from which it passes through a drain and conduit 22 to a sludge blanket steriliser 23, where it remains long enough for destruction of pathogens and softening of the husks and fibrous matter by the alkaline medium.

In the sludge blanket steriliser, pathogens will be flocculated by lime into the sludge blanket. Because the sludge blanket has a higher solids content than the inflowing limed slurry, the residence time of any element of this sludge blanket will be longer than that of the water which percolates through the sludge blanket. The solids component which needs sterilising will thus have a longer residence time than the water, which does not need sterilising. Economy in steriliser tank size is possible on this account.

When sterilised and softened the whole sludge passes over, through conduit 24, into an aerator 25, equipped with air blowing means 26 such as a sparger and air pump controlled by a dissolved-oxygen meter (not shown) in the aerator. Here activated sludge biomass is formed. Every effort is made, by feeding nutrient balancing additions 27 and the sterilised whole slurry into the aerator to yield the maximum amount of biomass which, after separation can be fed back to the livestock. Recycled water is used to dilute the sludge to a nutrient level suited to the action of microorganisms.

The content of calcium carbonate in the biomass is minimised by the presence within the aerator 25 of a limestone bed 25^1 upon which the calcium carbonate is deposited for periodic removal. The bubbles produced by the air-blow pass upwards through the limestone bed and prevent clogging. The void channels through this bed are sufficiently large to allow any biomass formed to slough off at intervals.

Activated sludge is passed from the aerator by conduit 31 to a separator 29. From here, clarified water is recycled through pipe 28 to the aerator, and further through pipes 34 and 35 to the pighouse as wash liquor for the floor and sump or for other use. Recycle water in excess of requirements is bled off through pipe 30. The maximum amount of water is recycled.

Settled biomass and fibre leaves the separator 29 by conduit 32 to be supplied as feedstuff to the pighouse, together with meal, as indicated at 21, containing energy-producing carbon compounds and proteinaceous components.

Some limed waste is recycled from sump

3 by conduit 36 to join the fresh lime hydrate supply at control point 19 to facilitate thorough mixing of the materials.

It is to be noted that the only products of this process are purified bleed-water, proteinaceous feedstuff supplement containing required fibre, and calcium carbonate.

It is in no way intended to limit the invention to the embodiment of Figure 2. It is clear to a worker competent in the subject that modifications may be made to suit the requirements of the particular farm. On some farms the need for production of an acceptable effluent water may be paramount. On others the need to avoid objectionable smells, and on still others the need to economise on land distribution charges and obtain an economic value from the feedstuff supplement.

The addition of nutrient for the aerobic biomass of carbonaceous materials to be softened in the alkaline sterilisation process is not indicated in the diagram. The use of, for example, chopped straw, evidently depends upon the availability economically on the particular farm.

As an alternative to the limstone bed referred to in connection with Figure 2, granular calcium carbonate may be used.

An advantage of this particular embodiment of the invention is that, with the whole slurry passing to the aeration tank there may be no need to add a compound providing phosphorus. The addition of granular calcium carbonate to act as a nucleus for the deposition of calcium carbonate in the aeration tank incurs no complication because a mixture of this calcium carbonate and the quicklime can be fed simultaneously into the system from the one silo. Dissolved-air flotation may be used to separate biomass from the granular calcium carbonate.

The following Examples are given for the purpose of further illustrating the invention.

EXAMPLE I

Demonstrates the necessity for treatment of slurry with lime soon after excretion.

A gilt weighing approximately 40 kg was kept for three weeks in a metabolism crate and fed on barley and water. Faeces and urine were collected separately and analysed for total (ammonia and urea) nitrogen. Samples were stored at room temperature with and without the addition of lime and mixed slurry. Samples of mixed slurry, as fresh as possible, were halved and one half treated with lime to pH 11. Some slurry samples were made up by mixing faeces and urine in the ratio 1:2 and adding lime immediately.

Organic nitrogen was measured by the standard Kjeldahl method. Ammonia nitrogen was measured by steam distillation and back titration. Urea nitrogen was measured by the diactyl monoxide thio semicarbazide method.

Urea levels during storage of urine at 20°C. mg/l as urea

Sample	Day 0	Day 3	Day 4	Day 6	Day 10
1	25.0	23.5	25.0	25.5	26.5
2	22.0	18.0	11.5	12.5	0
3	27.0	22.0	25.1	23.7	26.5

Sample	Treatment
1	Urine stored in a glass container with a cottonwool plug.
2	As 1 with a 10 per cent addition of mixed slurry.
3	As 2 with lime added.

With Sample 1 there was no decrease in urea content after ten days' storage. This shows the absence of urease enzyme or microorganisms able to produce this in the urine. With the addition of the faeces to the urine as in Sample 2 the urea content decreased to zero after ten days. This shown the instability of the urea even with the addition of only a small proportion of faeces. Sample 3 shows that with the addition of lime to give pH 11 there was little or no decrease in the urea level even though urease-producing microorganisms were present.

EXAMPLE II

Shows that if lime is not added soon enough, there is loss of ammonia, but that the remaining urea is then stabilised.

Slurry was obtained having faeces and urine in the proportion of 1:2 by weight. Owing to the difficulty in obtaining a completely fresh mixed sample the slurry had been left for several hours. The slurry samples were halved and lime was added to one to give the pH of 11. Analytical results after different periods of storage are shown below. On addition of the lime there was an intolerable smell of ammonia.

Analyses for organic and urea nitrogen after different times of standing are given below.

Storage of 'fresh' slurry					*mg/l at N*	
	Day 0	Day 1	Day 2	Day 5	Day 12	
NH_4	3.4	8.1	7.6	7.7	—	Sample without lime
Org.	8.9	4.6	4.8	4.6	—	
Urea	5.6	0	0	0		
NH_4	.84	2.17	.95	.42	.15	Sample with lime
Org.	11.0	10.2	10.4	11.0	11.9	
Urea	5.6	—	7.7	8.2	5.8	

The analyses of the sample without lime show that there was a very rapid fall in the content of urea nitrogen to zero and a slow fall in the organic nitrogen. With the lime, however, there was no indication of a decrease of urea nitrogen or organic nitrogen.

The reason why the use of lime with animal farm slurry has not been suggested in the past is loss of ammonia and the objectionable result. The Example shows that the decomposition of urea under farm conditions is very rapid. It also shows that even though some ammonia production has occurred, the addition of lime stops further decomposition.

EXAMPLE III

Shows that organic nitrogen is also stabilised by lime.

An experiment was carried out with a further sample of mixed slurry. In this case the time of standing was shorter so that little ammonia was driven off from the limed sample. In the limed sample there was an apparent gain of urea. This was due to evaporation as can be seen by the increase in organic nitrogen:

Storage of 'fresh' slurry				*mg/l at N*	
	Day 0	Day 3	Day 10	Day 17	
NH_4	1.7	5.3	5.7	7.6	Sample without lime
Org.	11.7	5.2	5.2	8.3	
Urea	7.8	0	0	0	
NH_4	1.7	.7	.33	.27	Sample with lime
Org.	11.7	12.1	13.9	17.8	
Urea	8.6	8.9	9.3	12.2	

This Example further confirms the basic discovery upon which the present invention is based—namely that if the lime is added to the mixed urine and faeces sufficiently soon after excretion there is little or no unpleasantness due to loss of ammonia and the urea then remains effectively stable.

WHAT WE CLAIM IS:—

1. A method of treating animal waste arising in animal husbandry in an animal house to obtain products useful on the land or in animal feedstuff, which comprises contacting fresh animal dung and urine from mammals in an animal house before more than 25 per cent by weight of the urea initially present on excretion has been converted to ammonia or ammonium compounds, with a sufficient proportion of lime or a mixture containing lime, to form an alkaline slurry of the dung and urine having a pH value of from 9.0 to 12.0.

2. A method according to Claim 1, wherein said pH value is at least 11.

3. A method according to Claim 1 or 2, wherein the animals husbanded are pigs.

4. A method according to any of Claims 1 to 3, wherein the mixed dung and urine are contacted with the lime before any appreciable odour of ammonia can be detected.

5. A method according to any of Claims 1 to 3, wherein the mixed dung and urine are contacted with the lime within 30 minutes of excretion.

6. A method according to any preceding Claim, wherein a dung collecting zone of an animal house is automatically washed recurrently with an aqueous liquor containing said lime.

7. A method according to any of Claims 1 to 5, wherein a dung collecting zone of an animal house is continuously washed with aqueous liquor containing said lime.

8. A method according to Claim 6 or 7, wherein said aqueous liquor contains recycled alkaline slurry.

9. A method according to Claim 8, wherein the recycled liquor comprises supernatant liquor separated from alkaline slurry.

10. A method according to any preceding Claim, wherein the lime is provided in the form of quicklime, by hydrated lime, by lime putty or by milk of lime.

11. A method according to any preceding Claim, wherein the alkaline slurry is retained at said pH for a period of time sufficiently long to inactivate at the temperature of retention effectively all pathogens present, to yield at least one sterile product applicable to land as fertiliser or soil conditioner.

12. A method according to Claim 11, wherein the sterile product is a mixed slurry or comprises a substantially clear supernatant liquid product separated therefrom and a thickened sediment product with a calcareous content.

13. A method according to Claim 12, wherein a stackable fibrous solid is separated from said sterile product to leave a suspension.

14. A method according to any of Claims 11 to 13, wherein at least part of said resulting sterile product is treated by an aerobic microbiological process in such a way as to establish and maintain an effectively stable population of microorganisms, optionally with nutrient additions influencing the balance therein of carbon, hydrogen, nitrogen, phosphorus and potassium to yield an effectively pathogen-free biomass applicable as an animal feedstuff supplement.

15. A method according to Claim 14, wherein the microbiological process is performed at an elevated temperature not exceeding 50°C sustained at least in part by animal body heat retained in the dung and urine and heat of hydration of lime when used.

16. A method according to any preceding Claim wherein a weighting agent such as granular calcium carbonate is mixed in the slurry.

17. A method according to any of Claims 14 to 16, wherein calcium carbonate is precipitated from the sterilised liquor, under the influence of carbon dioxide developed in the digestion.

18. A method according to Claim 17, wherein calcium carbonate is precipitated onto a limestone bed or onto granular calcium carbonate and removed thereon.

19. A method according to Claim 17 or 18, wherein calcium carbonate is separated from the biomass by a dissolved-air flotation process.

20. A method according to any of Claims 11 to 19, wherein the whole sludge is treated by the microbiological process.

21. A method of treating animal waste to obtain products useful on the land or in animal feedstuff, substantially as described with reference to Figure 2 of the accompanying drawings.

22. A pathogen-free alkaline material for use on the land, in the form of a slurry, a sediment, a fibrous material or a supernatant liquid, produced by the method of any of Claims 10, 11, 12, 14 and 20.

23. Biomass produced by the method of any of Claims 14 to 21, and applicable as an animal feed supplement.

24. Apparatus for carrying out the method of Claim 1, on dung and urine freshly deposited in an animal house with collection means therefor, which apparatus comprises supply means in the animal house, controlled in response to pH value in the collection means and effective to feed the lime to said collection means containing freshly deposited dung and urine, in amounts of lime to form the alkaline slurry therein and maintain said alkaline slurry at the required pH.

25. Apparatus as claimed in Claim 24, including a quicklime store protected against carbonation and premature hydration of the lime, metering means responsive to slurry pH for feeding the lime, and a hydrator for producing said lime as milk of lime from the quicklime.

26. Apparatus as claimed in Claim 24 or 25 for carrying out the method of Claim 11, and further comprising means for storing the alkaline slurry for the residence time required to inactivate the pathogens.

27. Apparatus as claimed in Claim 26, wherein said storage means is an upward flow sludge blanket clarifier.

28. Apparatus as claimed in Claim 26 or 27, further comprising means for separating liquid from solid in the sterilised slurry.

29. Apparatus as claimed in Claim 26, 27 or 28 for carrying out the method of Claim 14 and further comprising an aerator suitable for an aerobic microbiological process of the activated sludge type, with means for continuous supply of said sterile product thereto.

30. Apparatus as claimed in Claim 29, wherein calcareous material is removably located in the aerator, for deposition there-

on of calcium carbonate produced by reaction of lime and carbon dioxide from the aerobic microbiological process.

31. Apparatus as claimed in Claim 29 or 30, wherein means are also provided for separating liquid from solid in the aerobically processed slurry.

32. Apparatus for carrying out the method of Claim 14 substantially as described with reference to Figure 2 of the accompanying drawings.

For the Applicants,
CARPMAELS & RANSFORD,
Chartered Patent Agents,
43 Bloomsbury Square,
London WC1A 2RA.

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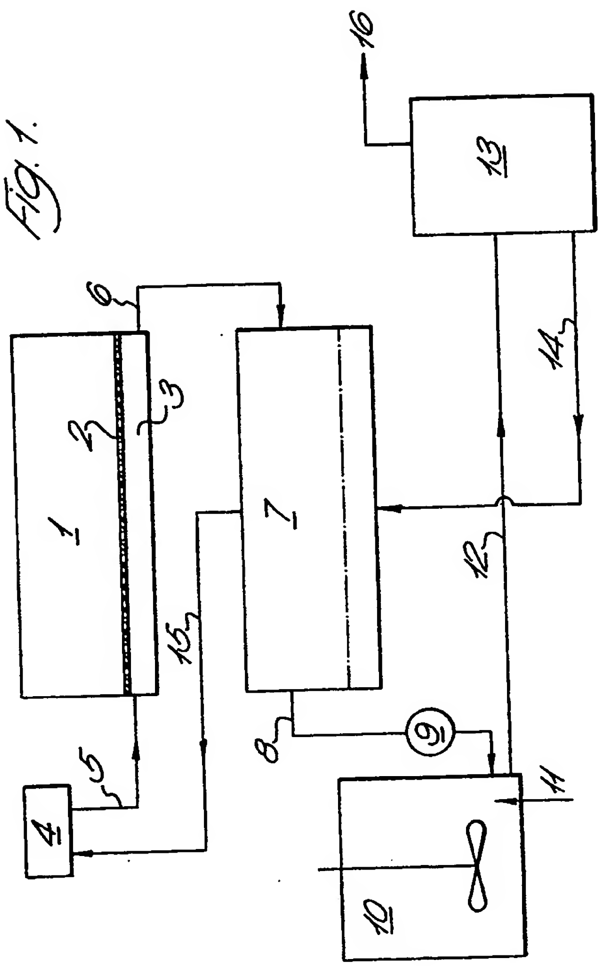

Fig. 1.

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1567773 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

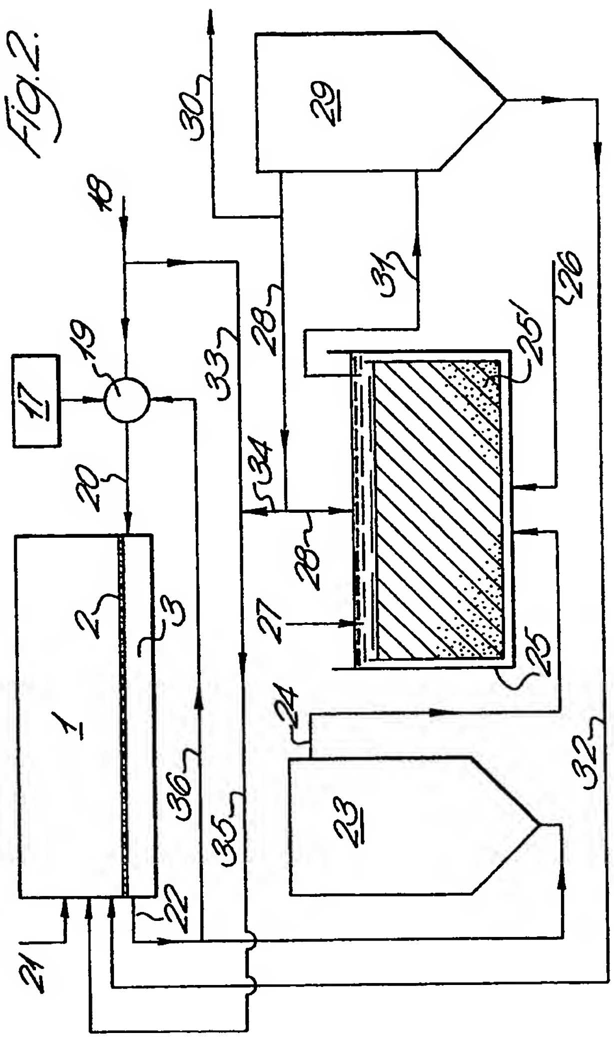

Fig. 2.